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ABSTRACT

This paper presents a case study of the Puerto Rico Statewide Systemic Initiative (PR-SSI) based on the analysis of data gathered from semi-structured interviews with key officials, field notes from site visits, progress and evaluation reports, and documents used in dissemination workshops for teachers. Although substantial data on student achievement are not available at this time, the qualitative analysis conducted here indicates that the PR-SSI is implementing an innovative reform program that deserves close attention. The path toward more effective schools was laid out by the PR-SSI as the direct result of simultaneously developing and implementing a variety of strategies to tackle all elements involved in making education reform systemic, i.e., policy, curriculum, student assessment, professional development, project evaluation, monitoring, and administrative support. Also, the PR-SSI articulated a form of conceptual systemic clarity throughout the initiative that became the cohesive theoretical and ideological force driving the reform effort forward. (Author/KHR)

Research Monograph No. 14

Equity through Systemic- Reform: The Case of Whole-School Mathematics and Science Restructuring in Puerto Rico

Alberto J. Rodriguez

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Research Monograph No. 14

**Equity through Systemic Reform: The Case of Whole-School
Mathematics and Science Restructuring in Puerto Rico**

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Abstract

Even though Puerto Rico is a small Caribbean island, it has a population of 3.8 million Spanish-speaking people. Puerto Rico is also very poor-the current per capita income is less than half that in Mississippi, one of the poorest states in the Union. However, Puerto Rico may have one of the most promising science education reform programs of all the sites funded by the National Science Foundation's Statewide Systemic Initiative (SSI) reform program. This paper presents a case study of the Puerto Rico Statewide Systemic Initiative (PR-SSI) based on the analysis of data gathered from semistructured interviews with key officials, field notes from site visits, progress and evaluation reports, and documents used in dissemination workshops for teachers. Although substantial data on student achievement are not available at this time, the qualitative analysis conducted here indicates that the PR-SSI is implementing an innovative reform program that deserves close attention. The path toward more effective schools was laid out by the PR-SSI as the direct result of simultaneously developing and implementing a variety of strategies to tackle all elements involved in making education reform systemic (i.e., policy, curriculum, student assessment, professional development, project evaluation, monitoring, and administrative support). Also, the PR-SSI articulated a form of *conceptual systemic clarity* throughout the initiative that became the cohesive theoretical and ideological force driving the reform effort forward.

Introduction

Since 1991, 26 states have received support from the National Science Foundation's ambitious Statewide Systemic Initiative [SSI] reform program (Shields, Corcoran, & Zucker, 1994c). Systemic reform "involves reforming and restructuring the entire enterprise of education, from the level of national goals to state curriculum frameworks, on to the district, the building, the classroom, and the teacher" (Sashkin & Egermeier, 1993, p. vi). This approach to reform is different in that it acknowledges how deeply interconnected all the driving elements of the educational enterprise really are (O'Day & Smith, 1993). Hence, systemic reform not only seeks to transform the structures and process of how education is carried out, but the culture of schooling as well. This orientation to reform holds the best promise for success, because, as Andy Hargreaves (1989) stated, there can be no change in teacher culture without supportive structural changes in how teachers conduct their work.

Needless to say, this is easier said than done. The complex sociocultural, institutional, financial, and political issues that affect the schooling process have shown in the past how difficult it can be to get all stakeholders to agree on a common path. In the case of 'systemic reform, this task is more complicated because it has required a leap of faith since its inception. That is, since systemic reform is a new approach to improving education, we know little about how to implement it and how to assess its progress. For example, SSI evaluation reports have shown that, even though some states had implemented new content science standards, they did not provide local or state educational authorities with a mechanism to assess these new standards. In other states, like Kentucky, comprehensive assessment programs were used for two years before the new curriculum guidelines were available to teachers (Shields, Corcoran, & Zucker, 1994a, 1994b, 1994c; Zucker, Shields, Adelman, & Powell, 1995; Adelman, Corcoran, Hawkins, Shields, & Zucker, 1995).

Problems of this nature are not surprising considering the magnitude of some SSI programs. Just the sheer size of some of the states involved (e.g., California and New York) or the complexity of attempting to coordinate reform programs across independent agencies, such as boards of education, school districts, etc., creates a cacophony of issues that demand creativity, perseverance, and political will.

Hence, it is important to begin to identify those programs that have made the most inroads at various levels, especially regarding equity issues. Although equity is rarely explicitly defined in major reform documents, it is a major goal in current education reform efforts, and the importance of this goal has increased as more people have become concerned about the persistent gap in performance and participation on national tests and college entrance exams between traditionally underserved students (i.e., women, the poor, and students of African, **Latino/a** [Hispanic], and First Nations [Native American] ethnic backgrounds) and middle and upper class Anglo-European and Asian students (National Science Foundation, 1994, 1996; Rodriguez, 1997a).

In this study, equity is defined as the act of consciousness by which fundamental laws and policies are enacted to ensure the fair distribution of resources leading not only to equal opportunities for access, but equal opportunities for successful outcomes in each individual's right to pursue intellectual and social growth. Equity must become an act of consciousness to

emphasize that each one of us is implicated in whether, and how, equity policies are enacted in our teaching practice, in our research, and in our everyday life. Similarly, the *term fair* is used to stress that equity is not the same as equality. Fair treatment has to do with ensuring that the needs of each individual, or group of individuals, are met *because of* their differences in culture, religious beliefs, gender, ability, representation, socioeconomic status, sexual orientation, family composition, and/or second language proficiency. Finally, equity policies must lead to equal opportunities for successful *outcomes*, because enhanced opportunities for equal access mean little, unless equally important retention and support programs are also put in place.

So far, the Puerto Rico Statewide Systemic Initiative (PR-SSI) has emerged as one of the most *promising* and *innovative* reform programs seriously addressing the intersection of systemic reform with equity issues. This paper provides a detailed analysis of how key players in Puerto Rico are implementing the difficult modifications in curriculum, pedagogical approaches, policy, and assessment required to effect systemic change. Even though the PR-SSI is far from completing its goals, and even though the PR-SSI has not yet accumulated sufficient data on student achievement to make empirical claims on the effectiveness of its reform efforts, we need to gather insights on the process of *promising* reform efforts. It may very well take many years before significant changes in the culture of teaching yield the kind of growth in student achievement everyone expects of systemic reform; therefore, a better understanding of ongoing and promising systemic reform efforts will be helpful to many others who are working in existing and/or new systemic initiatives.

Method

An extensive review of available research and evaluation reports showed that very few SSI sites promised to have a significant impact on equity issues. That is, few SSI sites had policies aligned with changes in curriculum, professional development, and assessment that would drive improvements in the achievement and participation of traditionally underserved students. From this small pool, key sites were selected for further analysis on the basis of their willingness to share information prior to a site *visit*.¹

Once a key site was selected, a more in-depth study was conducted. That is, in addition to reviewing all of the standards and curriculum documents, as well all of the research and evaluation reports, data were gathered from the analysis of semistructured interviews with key officials (Spradley, 1979). For this case study, a total of seven key officials (from experienced teachers in the role of dissemination coordinators to principal investigators) participated in a 90- to 120-minute interview each. All interviews were conducted in Spanish by the principal investigator and transcribed in Spanish by native speakers. With the exception of progress reports prepared for NSF, most of the documents collected were also in Spanish. Thus, all quotes used in the paper were translated by the principal investigator. Copies of this manuscript were made available to each participant for comments and suggestions. No pseudonyms are used. Field notes from site visits as well as documents commonly used in dissemination workshops for teachers were also

¹ Several of the *SSIs* were unwilling to make information available. In most cases, several telephone calls were required to obtain progress reports, and in some cases reports and other materials were never received.

used for further analysis and triangulation (Goetz & LeCompte, 1984; Hammersley & Atkinson, 1983; Wolcott, 1985).

A case study approach to data gathering and analysis was used as suggested by Patton (1987) and Lincoln and Guba (1985). Patton (1987) describes well the advantage of case study research when he explains that

case studies become particularly useful when one needs to understand some particular problem or situation in great depth, or identify cases rich in information-rich in the sense that a great deal can be learned from a few exemplars of the phenomenon in question. (p. 19)

Stake (1980, cited in Lincoln & Guba, 1985) adds that "case studies will often be the preferred method of research because they may be epistemologically in harmony with the reader's experience and thus to that person a natural basis for generalization" (p. 120). While the results of this case study cannot be generalized across systemic initiatives, insights drawn from understanding the process of reform in the PR-SSI could add to the repertoire of possibilities needed to meet the challenges of implementing systemic reform in other similar institutional and social contexts.

In the case of Puerto Rico, to better understand its progress in systemic reform, one also needs to gain a better understanding of the island's socioeconomic and political contexts.

The Socioeconomic and Cultural Contexts of Science and Mathematics Education in Puerto Rico

Many people are not aware of the special status Puerto Rico has in the United States. Puerto Ricans do not vote in U.S. elections; hence, they do not have representatives in the U.S. Congress. In short, Puerto Rico is not a state; it is considered *an Estado Libre Asociado* or an associated free state belonging to the U.S. commonwealth.

Even though Puerto Rico is a small 100 mile by 35 mile Caribbean island, it has a population of 3.8 million. This population is larger than that of 26 states in the U.S. Due to its centralization, the Puerto Rico school system also has the second largest student population in the U.S. (650,000 students; Gomez, 1996). The per capita income of Puerto Ricans is currently less than half that in Mississippi, and 14% of the population was unemployed in April 1997. In the U.S., the unemployment rate dropped from 5.2% in March of the same year, to 4.8% in April.

Due to high levels of poverty in Puerto Rico, the development of highly skilled human resources is one of the principal strategies for the social and economic growth in the island. One can also expect that the improvement of educational opportunities for Puerto Ricans will benefit the overall U.S. economy. For instance, the University of Puerto Rico (Mayaguez campus) and the Polytechnic University of Puerto Rico awarded the largest number of engineering degrees to **Latinos/as** of any U.S. university in 1993 (NSF, 1996). In fact, in 1993, Puerto Rican universities graduated more **Latino/a** engineers than all of Florida International University, the main campus of the Texas A&M University, the University of Texas at El Paso, the California Polytechnic State University, the University of Texas at Austin, and the Massachusetts Institute of Technology combined (NSF, 1996). In addition, almost 30% of all the engineering degrees were

conferred to **Latinas** in the Mayaguez campus in 1993. On one hand, this is cause for celebration, but on the other, it is cause for alarm. We should all be concerned that in spite of the pervasive poverty Puerto Rican students face at all school levels, two main Puerto Rican universities produce more **Latino/a** engineers than the combined total of **Latino/a** engineers produced by any of the universities more commonly attended by Latinos in the U.S. mainland. These statistics are also alarming when one considers that, according to the U.S. 1990 census, Puerto Ricans are the third largest **Latino** group in the United States (about 11%). Chicanos or U.S. Mexicans are the largest (about 63%), and other **Latinos/as** (Latinos from all other Latin American countries) represent 14% of the U.S. **Latino** population. Demographic projections indicate that Latinos will become the second largest ethnic group in the U.S. by the year 2010 (Day, 1993).

If **Latinas/os** are the fastest growing ethnic group in our elementary and secondary schools (Smith et al., 1995), why is it that only 5% of all the science and engineering bachelor's degrees awarded in 1993 were received by Latinos? (NSF, 1996). Elsewhere, Rodriguez (1998a) argues that tracking may be one of the main factors contributing to the persistent gap in student achievement and participation in science. The results of tracking and unequal opportunities to learn are also reflected in how underrepresented students who do complete high school and have college aspirations are dramatically outperformed by Asian and Anglo-European students in college entrance exams such the Scholastic Aptitude Test, the American College Test, and Advanced Placement exams (Rodriguez, 1997a). Of all the U.S. **Latino** groups, Puerto Ricans typically score lowest in the verbal and math components of the SAT and in Advanced Placement exams. Therefore, what we can learn about successful systemic reform efforts in Puerto Rico promises to have a positive impact not only on Puerto Ricans who live on the Island, but on all **Latinos/as** who live on the U.S. mainland. Insights gained from this study could be used by others to inform systemic reform efforts in similar school contexts where there is a high density of **Latino/a** students, English as a Second Language learners, or students from low SES. We may also learn how to address the constantly high dropout rate for **Latinas/os** who, at a rate of up to 35%, have had the highest dropout rate in the U.S. for the last 25 years (Secada et al., 1998).

Equity and Systemic Reform in Puerto Rico

A cada niño un futuro, a cada niño su estrella.
(To each child a future, to each child his/her star.)

— Slogan of the Puerto Rico Department of Education

Figure 1 provides the author's conceptualization of how the Puerto Rico SSI facilitated the interplay of key elements to enact mathematics and science education reform. The shape representing each element was selected purposely to illustrate the balance and interdependence of each component. Thus, Figure 1 is not meant to illustrate a lineal sequence of events. In fact, for reform efforts to be successful, several of the elements indicated need to be in place at the same time or at least be in the planning stages. In the case of the Puerto Rico SSI, data analysis indicates that *Systemic Conceptual Clarity* was the base on which all other components rested. It is explained in more detail below followed by a description of each of the other elements: *Initiating and Aligning Changes in Policy, Curriculum, and Assessment; Professional Development as Changing the Culture of Teaching; Growth in Student Achievement and Participation; and Strategies for Scaling Up and for Self-Sustaining Systemic Change.*

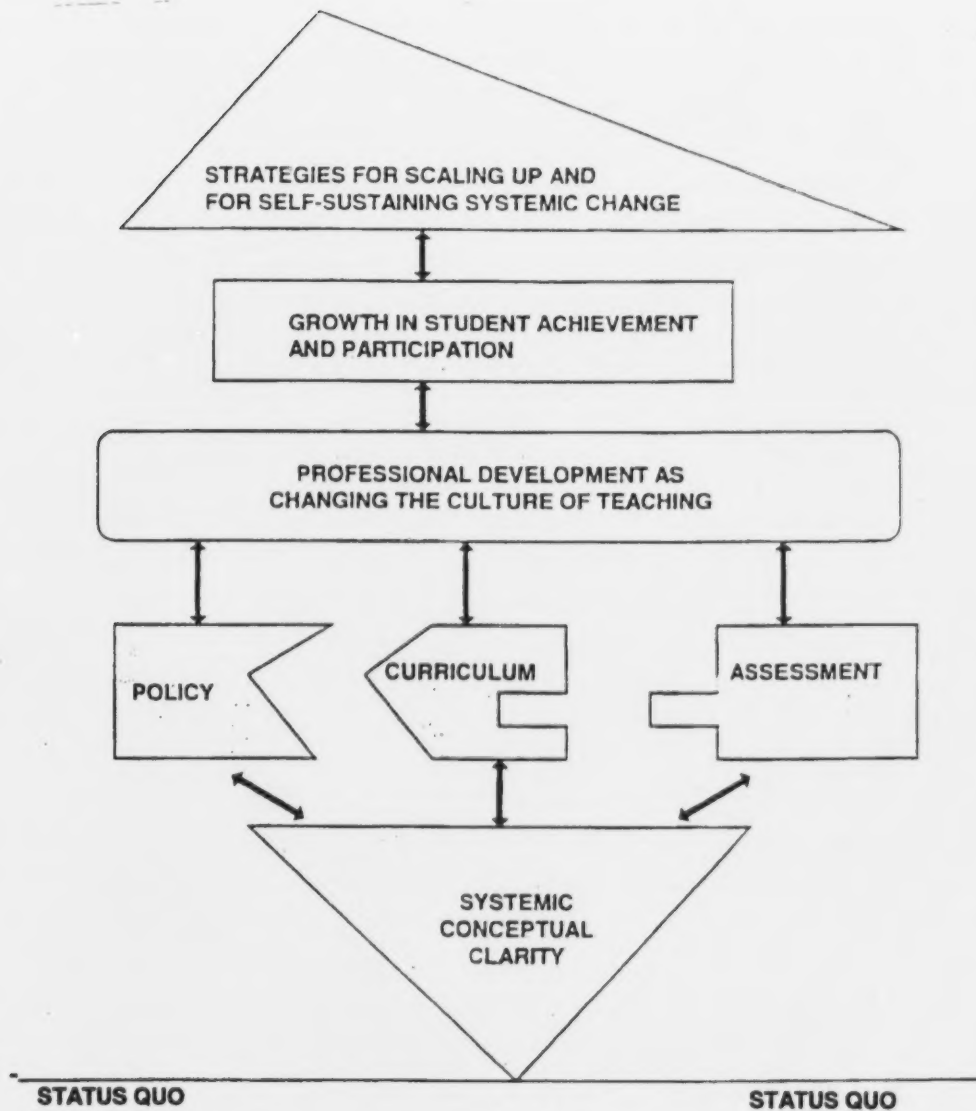


Figure 1. A model of systemic mathematics and science education reform: The Puerto Rico Statewide Systemic Initiative

Note: This figure represents the author's conceptualization of systemic reform in Puerto Rico and is not meant to suggest a lineal model. All components are driven by Systemic Conceptual Clarity.

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Systemic Conceptual Clarity

Systemic Conceptual Clarity is represented by an inverted pyramid in Figure 1 to indicate the tenuous balance PR-SSI officials were able to achieve to have teachers, administrators, parents, and politicians support vast pedagogical and curriculum changes. Analyses of the interviews conducted with all participants, as well as analyses of all documents collected (e.g., standards, curriculum, and internal reports), show a systemic conceptual clarity of the theoretical and ideological orientations driving the reform efforts. All participants explained at length how they perceived constructivism as the theory of learning that provided the best direction at this time for helping students learn science and mathematics for understanding.

For the sake of consistency, I must point out that elsewhere (Rodriguez, 1998b), I argued against the use of the term *constructivism* as a blanket term in science education. It is important to draw a distinction between individual constructivism and social constructivism. Individual constructivism is based on Piagetian perspectives that place the individual's mind as the locus of knowledge construction (Fensham, Gunstone, & White, 1994; O'Loughlin, 1992, 1993; Tobin, 1993). Social constructivism, on the other hand, suggests that knowledge is socially constructed and mediated by historical, institutional, and cultural codes (Bakhtin, 1981/1990; Wertsch, 1991; Gergen, 1995; Rodriguez, 1998b). From my point of view, members of the Puerto Rico SSI were engaged in promoting social constructivism at all levels, particularly as they articulated a keen awareness of the roles school culture and student socioeconomic status play in the reform process. Furthermore, the PR-SSI officials weaved the construct of equity throughout the whole reform initiative as a direct effort to tackle the reality of high poverty in public schools and the socioeconomic status of Puerto Rico. The need for increased academic success and participation in science and mathematics of students-especially students from very poor schools-was clearly in the minds of all the officials interviewed. For the sake of clarity and to honor the participants' voices in this study, I will use the term *constructivism* as they chose to use it during our conversations.

For example, Maria Sanabia (science) and Elba Velasquez (mathematics), both experienced teachers and coordinators of the middle school dissemination centers,² articulated that constructivism was the guiding theoretical orientation in their professional development work. In Sanabia's words,

Our design is basically framed by the belief that each student can construct his/her own knowledge; therefore, since we all share this vision, we design activities and model our strategic plan based on this focus. It is not easy, but we have been attempting to modify traditional teaching practices, and we are definitely getting teachers who have accepted the change and who are willing to continue this approach. They are convinced that the focus on constructivism is a better way of teaching. (Interview FME, p. 2)

Unlike many of the documents from other SSIs reviewed in preparation for this study, and unlike the National Research Council's *National Science Education Standards* (1996), one need not go further than the introductory pages of the Puerto Rico standards of excellence in science (Departamento de Educacibn, 1996a, p. i) or of the standards of excellence in mathematics

² These centers as well as other innovative features of the PR-SSI are explained later.

(Departamento de Educación, 1996b, p. i) to clearly understand that constructivism is the preferred theory of learning. For instance, it is stated in both standards documents that following a constructivist approach requires the teacher "to assume the role of facilitator and mediator of learning among the students. This presupposes changing from the traditional paradigm in which the teacher was the provider of information and the students were passive receptors" (p. i).

As explained in more detail below, this kind of systemic conceptual clarity in major reform documents provided some of the support and political leverage the PR-SSI needed to strengthen, continue, and expand its reform efforts. In contrast, the *NSES* (NRC, 1996), a significant science education reform document in the U.S., does not use the term *constructivism* even once in its 262 pages, although it is obvious that the NRC standards are based on individual constructivism (Rodriguez, 1997b).

How did the Puerto Rico SSI achieve the conceptual clarity observed? To answer this question, one must take a closer look at the individuals who led the reform efforts and their strategies for managing the demands and resistance to change. One of these key players is Manuel Gomez, principal investigator of the PR-SSI and director of the Resource Center for Science and Engineering at the University of Puerto Rico. Gomez is also a well-known professor of physics at the University of Puerto Rico (Rio Piedras campus). He has a long and successful history with the National Science Foundation, with top-ranking university officials, and with members of the government, business, and teaching communities.

From 1975 to 1986, Gomez was dean of the College of Science. He explains that as Dean he had "a systemic view" and was concerned "about not only the research aspects, which is what deans do in the university," but also began to be worried that the quality of teaching in schools "was not optimal, far from optimal" (Interview MG, p. 4). He added, "I was looking very carefully at the quality of students I was receiving from our schools, high schools, and I decided that precollege education needed a lot of reforming" (Interview MG, p. 4). These concerns motivated Gomez and others to apply for an NSF grant to create a K-12 professional development center. Thus, in 1980, the Resource Center for Science and Engineering was established with the support of the Rio Piedras campus of the University of Puerto Rico,³ the business community, and the Puerto Rican government. The center now involves the participation of postdoctoral students and others interested in improving the quality of education in Puerto Rico. In short, Gomez's ability to navigate successfully for almost two decades among distinct communities of practice has enabled him to gain a powerful and credible voice in science and mathematics education reform in Puerto Rico.

Initiating and Aligning Changes in Policy, Curriculum, and Assessment

The history of educational reform in the U.S. is marked by many unsuccessful attempts (Kliebard, 1992). Wishing to break this pattern, the National Science Foundation provided guidelines for its Systemic Initiative program that make clear the importance of linking policy,

³ The University of Puerto Rico is a multicampus public university system. The Rio Piedras campus is the oldest and is located in a suburb right outside San Juan, the capital of Puerto Rico.

curriculum, and assessment initiatives to produce effective change (Zucker et al., 1995). The Puerto Rico SSI demonstrates how the interplay of these key components can be managed and balanced to produce a pattern similar to that represented in Figure 1. Gomez, the principal investigator of the SSI, adds:

To be systemic you have to involve and affect several things, not one. For example, I could have just made a new curriculum as an alternate curriculum and given it to the schools. That would have failed. I could have gone into the school and empowered the teachers without giving them an alternate curriculum. That would have failed. I could have helped them, trained them on alternative assessment, and not provided a curriculum. That would have failed. If you see our whole school strategy, you will note that we have six thrusts, and all six have to be done simultaneously. So anyone who is a linear thinker shouldn't get into systemic reform. It's going to be a failure. (Interview MG, p.19)

The notion of *whole school* is a unique feature of the Puerto Rico SSI. This strategy essentially means that, for any one public school to receive support and professional development, *all* of its mathematics and science teachers have to agree to participate. This strategy is linked to professional development—one of the six thrusts Gomez considers to be essential for systemic reform. The other five thrusts or drivers are good standards, curriculum congruent with the standards, alternate forms of assessment, responsive management styles, and supportive evaluation and monitoring. To facilitate discussion, these thrusts are collapsed into three areas: policy, curriculum, and assessment. Each one of these key components is discussed next, keeping in mind that a lineal sequence is not being suggested (see Figure 1).

Policy. In 1990, the Puerto Rican government passed legislation calling for vast K-12 education reform (Departamento de Educación, 1996a). The emphasis of the law was to promote critical thinking and to ensure that educational opportunities were made accessible to all students. Gomez argued that this law was useful and needed, but it did not provide any specific guidelines for implementation at the school level. In 1993, the law was amended to provide a mechanism to decentralize the educational system. In this way, administrative autonomy was given to each school (Flores, 1994). In addition to decentralization, the education reform law also called for the creation of "estándares de excelencia" (standards of excellence) in all curriculum areas. PR-SSI officials in partnership with the "Consejo General de Educación" (General Council of Education), which is the organization in charge of licensing and accrediting schools in Puerto Rico, led the coordination and development of the science and mathematics content standards as well as of the assessment standards.

This climate of reform provided fertile ground for officials from the Resource Center for Science and Engineering (RCSE) and from the Puerto Rico Department of Education to secure NSF funding for reform under the auspices of the Statewide Systemic Initiative (SSI) program. Since it was the alliance of these two major players, and since the RCSE is a consortium of the institutions of higher education in Puerto Rico, the term PR-SSI is used to denote the membership and collaboration of a variety of organizations engaged in systemic reform in the island. This level of collaboration across organizations enabled PR-SSI officials to wear many hats in the process of reform. For example, María Sanabia, an experienced teacher on leave to work for the PR-SSI as a Dissemination Coordinator, also served on the Mathematics and Science Standards Committees of the Department of Education. The direct involvement of PR-

SSI members in standards, curriculum, and assessment committees provided additional opportunities for influencing and communicating policy changes across many levels.

Other important policies were established in support of the PR-SSI that added clarity to the original reform law. For instance, Puerto Rico is one of the few SSIs that has tackled science and mathematics education reform simultaneously (the way NSF expected it). For the PR-SSI officials, science education reform without mathematics education reform lacks meaning. This novel approach seems to take into account the students' point of view. (No empirical data are available on this claim, but several years of experience as a science teacher and as a biologist have taught me that, whereas mathematics may be the language of science among scientists, science is the language that makes mathematics more meaningful to children. For example, I know it has been easier, more socially relevant, and much more interesting to teach students about exponents by having them graph the exponential growth of bacteria or the exponential growth of the human population.)

As mentioned earlier, the Puerto Rico mathematics and science K-12 standards (Departamento de Educación, 1996a, 1996b) are now in place. The emphases of these standards are on equity, problem solving, integration of knowledge, and critical thinking. These objectives are congruent with those of the Educate America Act, Goals 2000 legislation (Smith et al., 1995), the NRC's science education standards (1996), the American Association for the Advancement of Science, Project 2061 (1989, 1993), and the National Council of Teachers of Mathematics standards (1989).⁴ The topic of assessment is discussed later, but it should be noted here that the PR-SSI also collaborated with the Council of General Education to develop "Estandares de Assessment para la Ciencia y la Matematica Escolar" (Assessment Standards for School Science and Mathematics, Departamento de Educación, 1996c). This document is also unique among SSI states because it provides clear definitions and guidelines on various alternate forms of assessment tools. For example, Standard 2 states, "The process of assessment must promote equity by offering each student opportunities to demonstrate his or her learning of math and science concepts" (p.23). The wording of this standard not only makes clear the importance of thinking about mathematics and science as closely linked disciplines, it also describes one way the construct of equity can be enacted in the classroom. It is further explained in the Assessment Standards document that using a variety of tools (concept maps, performance tasks, etc.) is not enough to meet the needs of each student. It is necessary for teachers to know the students' socioeconomic status, family, and cultural backgrounds, as well as differences in abilities.

One of Puerto Rico's strategies to deal with tracking and the pervasive gap in student achievement between students from public versus those from private schools is bold. The new high school graduation policy requires three years of science and three of mathematics (Puerto Rico-SSI, 1996b Progress Report). One of the science courses must be a year-long research course. Students are allowed to choose what the other two science courses will be. The PR-SSI

⁴ Even though there are many similarities between the PR-SSI education standards and key U.S. reform documents, I believe the PR-SSI standards go beyond agreement on the surface by paying closer attention to the unique sociocultural contexts in which students are expected to learn. This argument should become apparent as other elements of the reform initiative are explained.

approach to high school curriculum is to integrate the science disciplines wherever possible; therefore, integrated curriculum documents are being developed as part of the scaling up strategies at the high school level.

Curriculum. Mathematics and science curriculum reform in Puerto Rico was in an advanced stage before the SSI grant was awarded. According to Dr. Hector Joel Alvarez, K-12 Curriculum Coordinator, the Resource Center for Science and Engineering staff was involved in the process of curriculum reform at the intermediate (grades 7-9) level. The CRSE staff based their curriculum changes on guidelines suggested by NCTM and NRC standards, Project 2061, and the NSTA's Scope, Sequence and Coordination educational materials project. Alvarez, emphasizes that every effort was made to adapt the curriculum to the sociocultural realities of Puerto Rico. This adaptation is evident after close inspection of curriculum documents, where the use of inexpensive materials and connections to everyday life are emphasized.

It is not surprising, then, that the PR-SSI started with intermediate schools (grades 7-9). While the curriculum was being implemented at this level, the PR-SSI, in cooperation with the Department of Education, continued revision of the elementary (grades K-6) curriculum. In the 1995-96 school year, the K-6 curriculum was field tested in 23 elementary schools, and preparations began to design and field test the grades 10-12 curriculum in one high school.

Alvarez explained that the PR-SSI main curriculum focus has been on developing integrated curriculum at all levels. That is, a curriculum that enables students to connect scientific knowledge learned in one course with related knowledge in other disciplines. The high school curriculum continues this pattern. Since the new policy requires all high school students to take biology, chemistry, and physics courses every year, there is a strong need to develop new curriculum materials appropriate for each level. To this end, Alvarez indicated that a team of university mathematics and science professors, teachers, and PR-SSI staff had been meeting to explore meaningful ways to integrate the curriculum. Alvarez was emphatic about the importance of "integrating curriculum without watering down the integrity of the discipline" (Interview HA, p.5). In other words, Alvarez stated that his team makes every effort to find only meaningful connections across subject areas. He adds, "We do not want to integrate artificial things, we only do it where we can. If nature tells us, 'Look, here plants are neither physics, chemistry or biology, they are all together,' we take advantage of it and use it" (Interview HA, p.5).

One innovative way that Alvarez and his team have found for integrating mathematics and all other science areas is with the use of calculator-based labs. By using graphing calculators with temperature, light, and/or motion sensors, they are able to demonstrate to students how mathematics can be used to explain and explore scientific phenomena.

Assessment. Shortly after the Puerto Rico Mathematics and Science Standards were published, the "Estandares de Assessment para la Ciencia y la Matematica Escolar" (Standards for School Science and Mathematics Assessment) became available (Departamento de Educación, 1996c). These standards are framed in the spirit of the assessment standards for school mathematics of the National Council of Teachers of Mathematics (1989). Hence, the main focus of the Puerto Rico Assessment Standards is to help teachers understand alternate

procedures for obtaining information on what students have learned and are learning. . . . If the curriculum and teaching change in tune with the economic and social demands of the next millennium, so it is required to modify the techniques and instruments utilized for gathering information on students' learning throughout the educational process. (Departamento de Educación, 1996c, p. 3)

The PR Assessment Standards are divided into four sections. The first presents a frame of concepts and principles in support of the proposed assessment standards. The second section describes the standards themselves in detail. Just as it was in the PR Mathematics and Science Standards, equity is embedded as a central concept throughout the PR Assessment Standards. Standard 2 addresses equity most directly by stating that "equity is one of the most important principles of a democratic society and of an educational system. The assessment process must be examined under this standard if we desire to be just to all students" (Departamento de Educación, 1996c, p. 23). The third section of the PR-Assessment Standards provides concrete descriptions of alternate forms of assessments available to teachers. Each assessment technique is first defined in the document, followed by an explanation of the purposes of the technique and a detailed description of how it can be used in the classroom (Departamento de Educación, 1996c, p. 57). The last section of the PR Assessment Standards contains a bibliography of resources and appendixes (one of which contains a glossary of terms).

According to the PR Assessment Standards, one of the suggested procedures to meet the assessment standards-and to meet the standards' equity goals-is to provide students with a variety of alternate forms of assessment linked to their diverse needs. For example, the PR Assessment Standards state that attention must be paid to providing assessment opportunities responsive to the students' differences in gender, ethnicity, culture, socioeconomic status, and abilities. This is a daunting task given the high level of poverty in Puerto Rican's schools and the busy professional lives of teachers anywhere. However, the PR-SSI provides funds for teachers to attend workshops on assessment, as well as funds for buying some of the basic equipment required to meet curriculum changes.

Maria Sanabia and Elba Velasquez, two of the PR-SSI dissemination coordinators, also explain that their assessment workshops are successful because they are tied to the teachers' school contexts. All assessment materials used in professional development workshops are also modified to the sociocultural characteristics of Puerto Rico. Sanabia adds that teachers are encouraged to modify "whatever curriculum or assessment materials that fall in their hands to the realities of their own classrooms" (Interview FME, p. 10).

A review of many of the documents used in professional development workshops on assessment shows that suggested techniques are congruent with the PR Assessment Standards and the Mathematics and Science Standards. Some of the many alternate forms of assessment strategies being taught in professional development workshops are *ensayos* (essays), *mapas conceptuales* (concept maps), *lista de cotejos* (check list of skill performance), *diario reflexivo* (reflection journals), *rubricas* (rubrics), *cuestionarios* (questionnaires), *informes orales* (oral reports), *entrevistas* (interviews), *escalas* (scales), *preguntas abiertas* (open questions), *portafolios* (portfolios), and *tirillas comicas* (comic strips, Rodriguez, Negron, & Sanabia, 1995; Departamento de Educación, 1996c).

The use of comic strips is an innovative approach to help students illustrate their prior knowledge of mathematics and science concepts in a familiar and nonthreatening form. For example, in one of the professional development workshop (*talleres*) documents reviewed, there is one comic strip that is used to help students identify errors (Velasquez, no date). In the strip, one boy is reading the newspaper on the floor while another boy is making a messy peanut butter and jelly sandwich. The boy on the floor says, "It says here that 80% of all students in the country are weak in mathematics." To this, the other boy responds, "Wow! It is a good thing that I'm in the other 40%." Sanabia and Velasquez explain that lively conversations with participating teachers often take place on how this comic strip can be used with students in their own classrooms. In addition to having students correct the error in the comic strip, teachers can also ask students to white out the words in the conversation bubbles, and then write their own dialog based on the topic being covered. Depending on their artistic abilities, students are encouraged to draw their own comic strips and pose their own questions (Interview FME).

Finally, the PR Assessment Standards make clear that "valid inferences on student learning can be made only when what is learned corresponds to what was taught. Therefore, it is of vital importance that a close relationship exists between the teaching process and the process of assessment" (Department of Educación, 1996c, p. 44). In this regard, the PR-SSI strategies for professional development are discussed in more detail next.

Professional Development as Changing the Culture of Teaching

Policy, curriculum, and assessment documents are meaningful only as they become embodied in the everyday practice of teachers and in the success of each student. Perhaps this is what John Dewey wanted those attending the annual meeting of the National Education Association in 1901 to consider when he stated,

No matter what is the accepted precept and theory, no matter what the legislation of the school board or the mandate of the school superintendent, the reality of education is found in the personal and face-to-face contact of the teacher and child. The conditions that underlie and regulate this contact dominate the educational situation (cited in Kliebard, 1992, p. 103).

Aware of the important role teachers play to make systemic reform successful, most SSI states have given high priority to their teacher professional development programs (Zucker, & Shields, 1997; Zucker et al., 1995). The Puerto Rico SSI is not different in this approach, but what is unique about the PR-SSI is its focus on changing the teaching and learning *culture* of the schools, not just teaching practice. This orientation is tied to the PR-SSI officials' systemic conceptual clarity discussed earlier, and it was evident in various policies, interviews, and PR-SSI reports (Horizon Research Inc., 1996; PR-SSI, 1996a, 1996b). By seeking to change the teaching/learning culture of the schools, Gomez and Davila, the Evaluation and Assessment Coordinator for the PR-SSI, encourage teachers to see the SSI's efforts not as a passing trend, but as a model for continuing and collaborative professional development (Interviews MG and ND). Gomez and Davila suggest that one of the goals of the PR-SSI is to provide the means to empower teachers because "teachers are the agents of change" (Interview ND, p. 3).

However, research on teacher socialization (Cuban, 1992; Lortie, 1975; Zeichner & Gore, 1990) indicates how resistant teachers can be to change and how institutional codes conspire against

making change possible. Erickson, Mayer-Smith, Rodriguez, Chin, and Mitchell's (1994) work with preservice and inservice high school teachers also illustrates how difficult it can be to establish a collaborative and individual constructivist community of practice. In the Erickson et al. project, some of the teachers strongly objected to the student teachers' use of constructivist and student-centered pedagogical strategies. Even though these strategies were being explained and supported by the research team, some of the teachers felt the activities were too "airy-fairy"⁵ in terms of covering content and maintaining classroom control. Other studies also indicate how teachers, parents, and administrators are against teaching for diversity and against establishing equity programs (Atwater, 1994; Chang, 1993; Lee, 1996; Oakes, Ormseth, & Campbell, 1990; Rodriguez, 1998a; Wells, & Serna, 1996; Zeichner, 1992). What strategies did PR-SSI officials use then to tackle resistance to change in schools?

Essentially, three types of strategies were implemented: the whole school approach, experienced teachers leading professional development workshops, and responsive on-site support and follow up. The first, and perhaps the most important, was what Gomez calls the *whole school* approach. That is, before any kind of professional development support was provided, PR-SSI officials required the committed participation of *all* mathematics and science teachers in the school. According to Gomez, when all teachers who taught mathematics and science were willing and interested in participating in professional development workshops, the stage was set for beginning to change the teaching and learning *culture* of the school.

Involving all teachers within one school in systemic reform still must have required skillful persuasion and motivation. The Puerto Rican public school teachers had the motivation. They taught in poor conditions to mostly poor children and had a legal mandate to reform schooling (as mentioned above). The PR-SSI and the Department of Education developed (or were in the process of developing) supportive policies, new curriculum, and assessment practices. Now teachers needed to be persuaded to participate in professional development programs. This step ties to the second strategy, having experienced and well-recognized teachers lead the professional development workshops.

Although university faculty members were involved in professional development efforts, the bulk of the work with teachers was carried out by teachers themselves, including Elba Velasquez and Maria Sanabia, two of the dissemination coordinators mentioned above. According to Sanabia and Velasquez, sometimes teachers state that they "do not need this or that activity, but as time passes, they begin to experiment with one or two activities. Once the activities start to work in their classrooms, they begin to incorporate more and more of what was covered in the workshops" (Interview FME). A review of some of the documents used in the professional development workshops indicates that teachers are asked to participate in the same kinds of hands-on low-cost activities as they are expected to provide their students.

Coupled with professional development workshops were the opportunities for follow up and in-school support. These opportunities represented the third strategy PR-SSI officials used to facilitate change and ensure the effective implementation of the new curriculum and assessment

⁵ This term was used by some of the teachers participating in this year-long study.

practices. Sanabia and Velasquez explained that the initial workshops were four weeks long and conducted during the summer. The workshops focused on presenting the theoretical framework guiding the proposed changes, on specific strategies for collaborative and inquiry-based science and mathematics, and on strategies for alternate forms of assessment (Interview FME). The teacher participants also received eight 5-hour long Saturday seminars and several on-site visits during the school year. To date, 11 high schools, 49 elementary schools, and 132 middle schools have been involved in the PR-SSI, including the participation of 100,000 students and 2000 teachers.

Another unique aspect of the PR-SSI is that the lead teachers/dissemination coordinators have an office at their original schools. Each of these schools is also used as a dissemination center/model school. Even though the dissemination coordinators are experienced teachers on a leave of absence from their school duties, their presence within their school environment allows them to maintain close ties with teachers and students. Because of this contact with the teaching culture, Velasquez adds, "Teachers see us as equals and they trust and share with us their worries" (Interview FME, p. 7). The PR-SSIs strategies for professional development are promising, but what is needed next is a more in-depth study with teachers who have completed SSI training. This type of study with a sample group of teachers from each school level could provide more information on how effectively teachers are implementing in their own classroom contexts the standards and pedagogical strategies covered in SSI workshops.

Managing teachers' and administrators' resistance to change is one thing, but managing parents' resistance is another. Wells and Serna's (1996) research on tracking provides compelling examples of the sophisticated strategies parents of more privileged children implement to ensure that their offspring reap the benefits that come from membership in the culture of power. Sanabia explains that they too have encountered resistance from middle and high SES parents who feel that their children will not benefit from student-centered, collaborative learning. Sanabia argues that

children with supposedly higher intellectual skill must learn to share their knowledge with others. . . . This is an issue of clarifying values. We try to inform parents that in the new society in which they live great changes are needed. Finally, we sit with them and show them data on student achievement. This usually helps them understand the reality of the changes we are proposing. (Interview FME, p.4)

Velasquez and Sanabia also said that they often offer to attend parent-teacher conferences to help teachers explain the new changes in curriculum, assessment, and teaching practice. Parents, and indeed all stakeholders, need to know whether systemic reform in mathematics and science is having a positive impact on the participation and academic achievement of students in Puerto Rico. Of particular interest for this study is what the available data reveal about the effectiveness of the PR-SSI equity focus.

Growth in Student Achievement and Participation

Even though it is not quite fair to judge the effectiveness of any systemic reform initiative by how rapidly it improves student academic achievement and participation, it inevitably comes down to the "how much better" question. As mentioned earlier, systemic reform is a complex

process involving all elements of the schooling process. This type of reform is even more complex when, as in the PR-SSI, the vision for effecting school change is perceived as changing the culture of teaching and learning. Nevertheless, the questions of how much better students are doing, and how many more are taking science and mathematics as a result of the reform efforts, need to be asked. But these questions need to be asked and answered keeping in mind the differences in social, economic, political, and cultural contexts upon which the success or failure of any systemic reform initiative depends.

In the case of the PR-SSI, student performance and participation were monitored in two general forms. The first consisted of two external assessment tools, the Puerto Rico Assessment of Educational Progress (an adaptation of the National Assessment of Educational Progress or NAEP) and the **SENDA** (a standardized math test). The second general form used to monitor achievement consisted of three internal (PR-SSI staff designed) assessment strategies. These were pre- and posttests (including multiple-choice questions and performance assessment tasks), an analysis of students' grade distribution, and conducting questionnaires and interviews to evaluate the students' attitudes toward science. What follows is a brief explanation of the most significant external and internal assessment strategies. (Readers may want to consult the Puerto Rico Statewide Systemic Initiative proposal for Phase II, 1997, for more details).

In 1994, two years after the PR-SSI initially received funding, a Spanish version of the NAEP was administered in Puerto Rico (PRAEP). The test was conducted by Educational Testing Service and given to a representative sample of 12,000 grade 4 and 8 students. At grade 8 approximately 2,500 students from 7 public middle schools comprised the SSI school sample, and approximately 1,300 students from 59 private schools comprised the private school sample (Educational Testing Service, 1995a, 1995b). According to Davila (Interview ND), students from the SSI schools were a representative sample of the general public school student population in terms of all the major indicators such as percentage of students below poverty level, parental education. For example, Davila explained that the average percentage of students below the poverty level for SSI schools is 81% compared to 79% for all other public school students. This means that the average poverty level of both populations are within one standard deviation of each other, thus, making the PR-SSI schools representative of the general public schools in Puerto Rico. The other criterion used for the selection of SSI schools, was of course, the teachers' and administrators' willingness to participate in a comprehensive reform process of public schools.

Table 1 compares the scores on the PRAEP math and science tests from students in SSI, public, and private schools. Figure 2 shows how the scores for all three groups are below 250, less than 50% of the maximum possible score, and, as expected, students from private schools performed better than students from public schools. In spite of the low student performance, there are two important points to highlight here. First, the 1994 PRAEP provides significant baseline data for further analysis of student achievement. Second, private school eighth-grade students outperformed students from SSI public schools by only 13 points in the mathematics component of PRAEP. Whereas, private school eighth-grade students outperformed other public school students by 29 points (Educational Testing Service, 1995a, 1995b; Puerto Rico-SSI, 1997). This means that the gap in achievement between SSI-public schools and private schools was narrower by 16 points than the gap between other public schools and private schools (Figure 2). Similarly, private schools eighth-grade students outperformed SSI public schools students by 33 points in

the science component of PRAEP (see Figure 3), whereas, the difference in score between private and other public schools was 47 points in favor of private schools (Puerto Rico-SSI, 1997; Davila & Rodriguez, 1996). Thus, the gap in science achievement between private and public schools was 14 points less for the SSI public schools than for other public schools (Figure 3).

Table 1

Average fourth- and eighth-grade mathematics and science proficiency by type of school in the 1994 Puerto Rico Assessment of Educational Progress

Type of school	MATH SCORES		SCIENCE SCORES	
	Grade 4	Grade 8	Grade 4	Grade 8
Public	161 (1.2)	218 (1.1)	186 (1.1)	202 (1.2)
Private	195 (3.2)	247 (7.4)	219 (2.9)	249 (5.9)
PR-SSI	-----	234 (1.5)	-----	216 (1.8)

Note: The PRAEP math and science scales range from 0 to 500. The standard errors of the estimated statistics appear in parentheses. Therefore, it can be said with about 95 percent confidence that, for each population of interest, the value for the entire population is within ± 2 standard errors of the estimate for the sample.

Source: Educational Testing Service (1995a, 1995b) PRAEP Final Report 1994 Mathematics Assessment and PRAEP Final Report 1994 Science Assessment

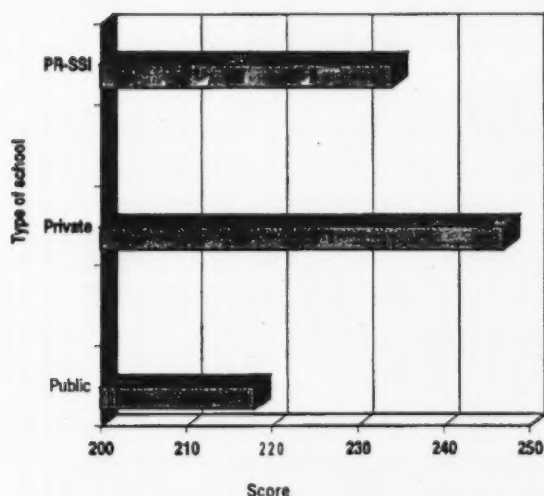


Figure 2. Average eighth-grade mathematics scores by type of school in the 1994 Puerto Rico Assessment of Educational Progress

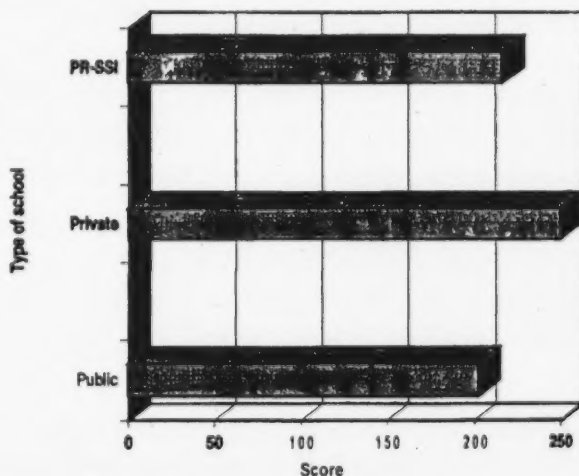


Figure 3. Average eighth-grade science scores by type of school in the 1994 Puerto Rico Assessment of Educational Progress

Considering that an average of 79% of all students from public schools are of low socioeconomic status by free and reduced lunch Federal guidelines, and considering that most of the private school students are of middle and upper SES, this difference in scores is significant in many ways. A more in-depth study of private schools would be useful for better understanding the traditional gap in achievement between private and public schools that goes beyond obvious differences in students' socioeconomic status. For instance, it would be useful to explore how differences in curriculum emphasis, teaching strategies, and tutorial support may have an effect on the achievement of students from private schools.

As a side note, scores for grade 4 students are not shown in Figures 2 and 3 because, at the time of the 1994 PRAEP test, the Puerto Rico systemic reform initiative had not yet expanded to elementary schools. Nevertheless, grade 4 data from public and private schools were collected for baseline purposes at that time. Results of the PRAEP test administered in 1997 are currently being analyzed, and they will provide useful data on the progress of both grade 4 and grade 8 students attending PR-SSI schools. The 1997 PRAEP results would also be drawing students from a larger pool of SSI schools since, at the time of the 1994 PRAEP, there were only 7 SSI middle schools (or approximately 2,500 students). These were the first schools to become models and dissemination centers for systemic reform in the island. (The PR-SSI scaling up strategies are discussed in the next section).

The second external assessment tool used to evaluate the progress of SSI students is the **SEDA**, which was designed by the College Board and administered by the Puerto Rico Department of Education. The **SEDA** is a standardized mathematics, Spanish, and English test. The results of the mathematics test for the 1994-95 school year showed that SSI grade 7 students scored an average of 244, whereas, non-SSI grade 7 students received an average score of 235. According to Davila and Rodriguez (1996), the difference was statistically significant.

Among the assessment tools used internally by the PR-SSI is a **pretest/posttest** battery. Julio Rodriguez, a faculty member at the University of Puerto Rico and one of the assessment and evaluation coordinators, explained that these mathematics and science tests are designed to measure content mastery, depth of understanding, and critical thinking (Interview JR). He also pointed out that the tests are congruent with the mathematics and science education standards because they contain performance-based components. A panel of teachers using rubrics scored the performance items and open-ended questions. PR-SSI officials trained the teachers to ensure high rater reliability (Davila & Rodriguez, 1996). Steps were also taken to select representative samples of students from first- (pilot) and second-generation middle schools to evaluate the value added to curriculum and teaching reform as a result of the PR-SSI intervention.

According to Julio Rodriguez,

in the last three years I have been involved with the PR-SSI, we have noticed that the profile of the first generation of students is similar to the next two generations. This indicates that the **SSI** is consistently enhancing student performance and that at least the high quality of education is being maintained across generations. (Interview JR)

Figure 4 provides an example of student achievement from first- and second-generation schools on the grade 7 physical properties performance task. Level 0 indicates poor understanding of scientific concepts, whereas level 5 indicates deep understanding and high level of performance.

As can be observed, most first- and second-generation students scored poorly in the pretest, but marked improvements were attained in the posttest. In addition, second generation students showed better performance at the satisfactory levels of 3 and 4. This pattern was also observed in the grade 7 use of scientific instruments performance assessment tasks, as well as in the first generation grade 8 pressure and force, biology, and earth science performance assessment tasks (Davila & Rodriguez, 1996).

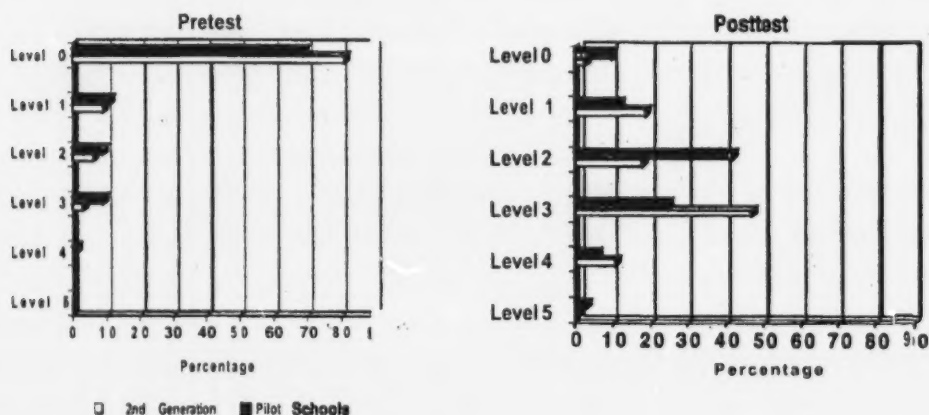


Figure 4. *Percentage scores on grade 7 science physical properties performance task. Pretest and posttest results for pilot schools and second-generation schools.*

Note: 369 students from 26 second generation schools and 69 students from 4 pilot schools participated in the posttest. 453 students from 26 second generation schools and 60 students from 4 pilot schools participated in the pretest.

Pilot tests were being conducted with grade 9 (third generation) students during the writing of this manuscript. Pilot studies were also being conducted at the elementary levels, since the PR-SSI was expanding from the middle schools to K-6 schools.

The next form of internal program evaluation to be discussed here is the monitoring of students' grade distribution in SSI schools. Figure 5 shows improvement in the distribution of A, B, C grades and a reduction of D and F grades in science and math. These students entered the SSI schools at grade 7 and were part of a cohort of 22 SSI middle schools where 83% of all students were below the poverty level. Figure 5 indicates that, by the end of grade 8, a favorable shift in the percentage of students receiving satisfactory grades in mathematics and science was attained.

Considering that the number of students participating in the second generation schools was over five times that of the first generation schools, and keeping in mind that substantial changes in pedagogy, curriculum, and assessment have been implemented in very poor schools, the improvements in student scores and grades supports the PR-SSI claims that reform efforts are having a positive impact on mathematics and science education in SSI public schools. There is, of course, a need for more detailed data on student achievement over time. Furthermore, there is a need to explore how teachers are connecting what they learn in professional development workshops with the different contexts of their classroom practice. Most systemic reform

initiatives have not gathered comprehensive information on the everyday happenings of the school classroom after teachers have participated in the reform process. This seems to be the next logical step in the evolution of understanding how to implement systemic reform.

A closer look at classroom interactions may also clarify why some students are still achieving so low on mathematics and science tests. Julio Rodriguez warns that "we need to continue to be cautious and not to think that everything is resolved. There are still a large number of students who are not doing well and who come from poor economic backgrounds" (Interview JR, p. 14).

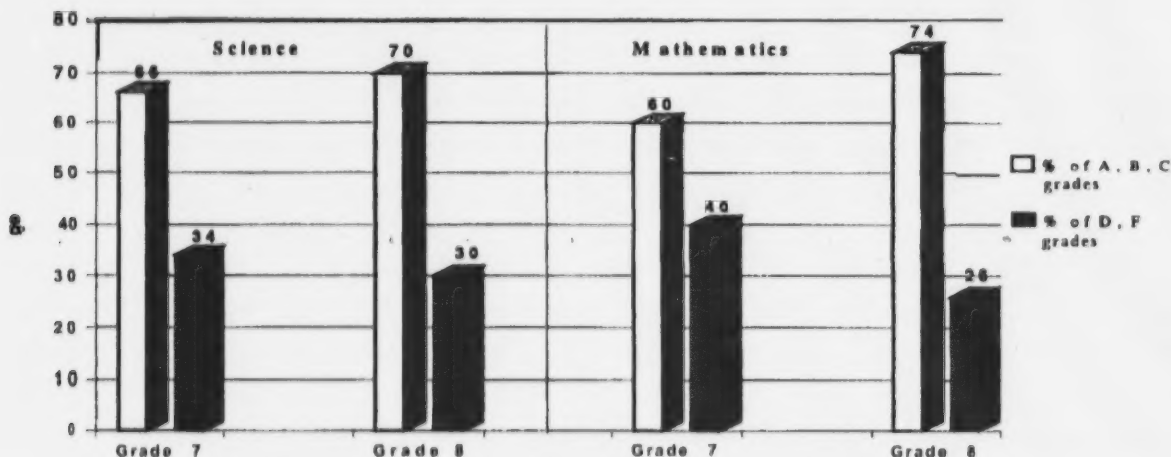


Figure 5. Longitudinal study of 22 PR-SSI schools illustrating grade distributions in mathematics and science for students who entered grade 7 in 1994-95.

Note: The average % of students below the poverty level attending the schools in this study was 83%

The PR-SSI should also provide data on student achievement broken down by gender. To date, none of the reports reviewed provided information on how well girls are performing in math and science compared to boys. Similarly, the PR-SSI should provide data on other **Latinos/as** (students who come from other Latin America countries) and students from nearby Caribbean Islands. Even though racism is not as much a social issue in Puerto Rico as it is in the U.S., the PR-SSI should provide data on the academic achievement of students who are not Puerto Rican.

Finally, information on student achievement lacked details in some progress reports. The PR-SSI could facilitate better understanding of its achievements by providing consistent and detailed information on student achievement reports. For example, the data shown in Figure 5 are useful, but it is not clear what the total number of students affected was, the gender distribution in the sample, how many schools were rural and how many were urban. In addition, some reports provided some statistical information, whereas others did not.

Strategies for Scaling Up and for Self-Sustaining Systemic Change

The **PR-SSI's** strategies for scaling up mathematics and science education reform are guided by a vision of having a self-sustaining infrastructure and culture that promotes ongoing teacher professional development. Thus, the pyramid-shaped structure representing strategies for scaling up in Figure 1 suggests that the success of the scaling-up process rests on the success of all other systemic reform elements. In other words, PR-SSI officials recognize that, by having expert and well-respected teachers leading workshops on policy changes, new curriculum, and innovative teaching and assessment practices, teachers would be more likely to truly explore the recommended changes.

The **PR-SSI's** scaling up strategies essentially consist of two stages: a pilot stage and a dissemination, or scaling-up, stage (Gomez, 1996; PR-SSI, 1996a). The pilot stage started with seven middle schools in 1993. Faculty members from the University of Puerto Rico and staff from the PR-SSI and the Resource Center for Science and Engineering provided the technical support and training required to implement the **SSI's** whole-school strategy explained earlier. Through the whole-school strategy, the PR-SSI provided all mathematics and science teachers in all seven schools with "multilevel simultaneous interventions to promote sustainable change in school reform instead of sporadic interventions which generally only produce short-term minimal results" (Davila & Rodriguez, 1996, p. 3).

Another important element in the **PR-SSI's** scaling-up strategy is to transform the pilot schools into dissemination centers/model schools by preparing and hiring some of the teachers in the pilot schools to become workshop leaders in other schools. This gradual, yet intensive, **scaling-up** approach enables the PR-SSI to create a critical mass of teachers and students that provides opportunities both to monitor the overall reform effort and to train teachers to sustain growth.

By the 1994-95 school year, 65 more middle schools represented the second generation of SSI schools. During this year, the PR-SSI also expanded the reform initiative to elementary (K-6) schools. By the end of the 1995-96 school year, 23 elementary schools helped complete the pilot and field testing of the new elementary curriculum. The same year, the pilot testing of the 10-12 curricula began in one high school. I attended one of the high school curriculum sessions focusing on making explicit how (and where) integration could be possible and relevant in the mathematics and science curricula. (It was impressive to observe the strong collaborative atmosphere at this meeting, where male and female faculty from colleges and high schools participated openly and actively regardless of their skin color, gender, subject area specialization, or years of teaching experience).

By 1997, systemic change in PR-SSI schools had reached almost 2,000 teachers, 100,000 students, and 200 schools. These figures represent about 16% of the K-12 teacher force, 15% of the total student population, and 12% of all schools. Impressively, these systemic reform efforts were accomplished with only \$10,000,000 support over five years from the NSF's SSI grant and over \$9,000,000 support from the University of Puerto Rico, the PR Department of Education, and the General Council of Education (Davila & Rodriguez, 1996). The National Science Foundation recently funded the PR-SSI for another five years, and by the end of Phase II, the **PR-SSI** hopes to impact close to 800 schools (half of the current total number of schools in Puerto Rico). The progress of PR-SSI should be closely watched during Phase II, since the foci will be

shifting to implementing the whole school strategy in high schools and in reforming teacher education programs. Historically, high school teachers have been more resistant to change, and preliminary evaluation reports from other SSI states confirm this. For example, Zucker and his associates (1995) state that, with the exception of the Montana SSI, "it is hard to find a state that has formulated a clear vision for reform of science and mathematics education at the high school level, let alone implemented it" (p. 11). Therefore, we would benefit from a better understanding of the PR-SSIs strategies for implementing systemic changes at the high school level.

Conclusion

This paper highlights the strategies the Puerto Rico Statewide Systemic Initiative has implemented (and is implementing) to improve the performance and participation of all students in math and science. The author's version of the PR-SSIs model for systemic reform is illustrated in Figure 1. Starting from the bottom, the inverted pyramid represents the difficult but necessary balance of key elements the PR-SSI maintains to make its reform efforts systemic and successful. Like pieces in a picture puzzle, all the different elements shown in Figure 1 depend on one another and are required to make the picture come into view. Although the process of systemic reform is far from complete in Puerto Rico, a picture of promising and ongoing systemic reform is beginning to emerge, which in turn enables us to draw insights for adapting similar strategies to related contexts in other sites.

I have also mentioned-without the intent of suggesting a sequential model in Figure 1-that Systemic Conceptual Clarity provided a cohesive drive throughout the reform effort. By openly articulating constructivism as a theoretical tool to guide teaching and learning, and by articulating equity as the ideological tool to effect social change, the PR-SSI focused on initiating and aligning all other elements required to make educational reform in Puerto Rico systemic and long lasting.

In addition to all the policy changes mandated by law, the involvement of various PR-SSI officials in curriculum and assessment committees enabled the PR-SSI to have a cohesive voice in the process of transforming the math and science curriculum. This involvement, in turn, promises to transfer well to teachers in the field, since several PR-SSI officials who contributed to the creation of new standards and curriculum were also dissemination coordinators/lead teachers responsible for conducting professional development workshops.

The PR-SSI also had a very aggressive strategy for implementing and scaling up the proposed systemic changes. They understood that funding was limited and that the culture of teaching and learning itself needed to be transformed if changes in student performance and participation were to be significant and ongoing. Therefore, the whole school strategy was a unique approach that required *all* math and science teachers in one school to be involved. Coupled with this approach was the notion that changes in curriculum, assessment, and pedagogical strategies needed to take place in both math and science simultaneously. The PR-SSIs vision of systemic change saw math and science as closely connected disciplines that, when taught in socially relevant and student-centered ways, could help students draw a deeper understanding of both subjects. The most powerful and persuasive tool the PR-SSI had to encourage teachers, parents, and administrators to become involved in systemic change was the apparent growth in student achievement and participation. The narrowing of the gap between students from private schools

and from PR-SSI public schools on the Puerto Rico Assessment of Educational Progress test (a Spanish version of NAEP) was a good indicator that the PR-SSI is heading in the right direction. The results of the most recent, 1997 PRAEP, are not out yet, but they deserve close attention. Other indicators of improved student performance discussed here were pre- and posttests as well as changes in grade distribution. Both of these consistently indicated that students from participating PR-SSI schools seem to be doing better, but more quantitative and qualitative data on achievement and participation over time are needed in order to make stronger empirical claims. A follow-up study could provide more detailed information, since the PR-SSI was awarded another five-year grant by NSF to continue scaling up the reform effort at all school levels. This should prove particularly interesting to study at the high school level where science and math teachers have traditionally been more resistant to change. In addition, a study involving in-classroom observation of teachers and students at all levels affected by the systemic initiative should yield valuable information on how well professional development strategies are being taken up by teachers.

Finally, Puerto Rico provided a fertile ground for reform due to the extent of poverty on the Island. As explained earlier, according to the free and reduced lunch Federal guidelines, 79% percent of students in public schools come from families below the poverty level. In many schools, this average is over 90%. Essentially, there are only three types of schools in Puerto Rico: private schools, poor schools, and very poor schools. Any improvement in student performance in Puerto Rico is very important in terms of equity.

Nevertheless, anyone who has ever been involved in any kind of reform in schools knows that it takes a great deal of commitment and political will to effect change. In short, appearing to have a disposition to act is not the same as acting on a disposition. The cohesive political will and high level of systemic conceptual clarity of all those participating in the PR-SSI created a critical mass that the National Science Foundation should seek to better understand in order to make productive decisions on who and/or what should be funded in the future.

Other case studies on the *process* of systemic reform such as the one presented here will provide deep insights and opportunities to contrast how those in charge of systemic reform initiatives manage the complex set of social, cultural, economic, and institutional factors that influence the effective implementation of systemic reform. This should help us to better understand how reform can actually work in various contexts. Norma Davila, the director of evaluation, explains that the PR-SSI "is using adaptations with innovations" (Interview ND, p.32), that is, using the collective knowledge of PR-SSI officials to innovatively adapt what is being proposed in the education reform and national standards literature to the unique socioeconomic and cultural contexts of Puerto Rican schools. In any case, how effective an adaptation and/or innovation is will be determined by its success at each school. This should be an essential component of systemic reform. Just like the effectiveness of a chain is determined by the strength of its weakest link, the effectiveness of systemic reform can ultimately be determined by the academic growth of students in the poorest schools.

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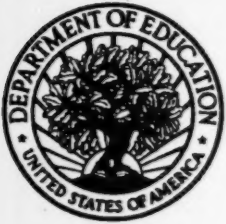
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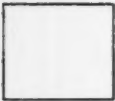


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